§41. The Effect of the Rotational Transform on Shafranov Shift

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The effect of rotational transform on the Shafranov shift in the neutral beam heated plasma has been experimentally investigated in Large Helical Device (LHD). In LHD, the rotational transform is controlled by changing the current distribution in helical coils which consists with three layers of superconductor. When the current center in helical coils is shifted towards the plasma, the effective minor radius a_{eff} becomes small and the central rotational transform increases.

The Shafranov shift of magnetic axis due to the Pfirsch-Scheluter current for the low beta limit can be expressed as

$$\Delta \cong \frac{aA_p{}^2\beta_0}{\iota(1)}\int_0^1 \frac{\delta_{1,0}(\rho)}{\iota(\rho)\kappa(\rho)}d\rho, \qquad (1)$$

where β_0 is the central beta, A_p is aspect ratio (ratio major to minor radius), ι is the rotational transform, κ is totoidal averaged ellipticity of cross section of magnetic flux surface, and $\delta_{m,n}$ is Fourier component of $1/B^2$ with m (n) is the poloidal (toroidal) mode number.

The magnetic axis is derived from the tangential soft x-ray image measured with the soft x-ray CCD in LHD. The position of the magnetic axis is derived from the best fit of measured x-ray intensity to that calculated soft x-ray intensity based on the magnetic flux surface derived using three-dimensional free boundary equilibrium code (VMEC).

Figure 1 shows the dependence of effective minor radius, central rotational transform and coefficient $aA_p{}^2/\iota(1)$, in eq. (1), on the pitch parameter of helical coil γ (= ma_{coil}/nR, where a_{coil} is distance between the plasma center and helical coil current center). The effective minor radius becomes small and the central rotational transform increases as the pitch parameter of helical coil is decreased. The coefficient $aA_p{}^2/\iota(1)$ increases as the effective minor radius is decreased with constant major radius.

Figure 2 shows the dependence of the Shafranov shift measured with the soft x-ray CCD camera as a function of averaged beta in the plasma with three central rotational transform ι(0) = 0.38, 0.46 and 0.57 at $R_{ax}{}^v$ = 3.60 m. Lines in Fig. 2 show the theoretical prediction calculated with VMEC code. The results are calculated for plasma with two plasma pressure profiles, $(1-\rho^8)(1-\rho^2)$ and $(1-\rho^8)(1-\rho^8)$. The Shafranov shift become small as γ is decreased because of larger central rotational transform even the coefficient $aA_p{}^2/\iota(1)$ is increased.

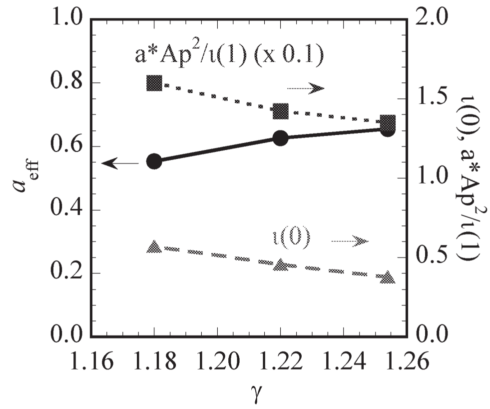

Fig. 1. Dependence of effective minor radius, central rotational transform and coefficient $aA_p{}^2/\iota(\rho)$ on the pitch parameter of helical coil γ.

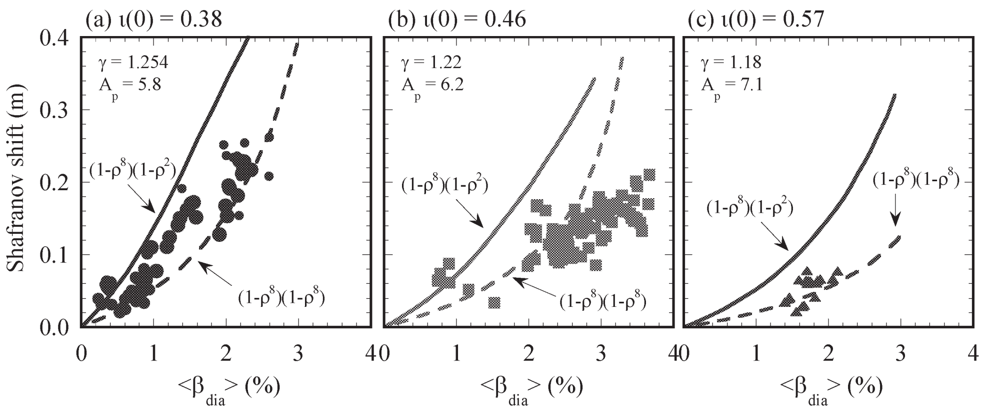

Fig. 2. Dependence of the Shafranov shift on the volume averaged diamagnetic-beta for three central rotational transform ι(0) = 0.38, 0.46 and 0.57 at $R_{ax}{}^v$ = 3.60 m and B_Q = 100 % configuration. The marks and lines show the experimental results and theoretical predictions calculated with VMEC code, respectively.